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## (54) A system for transmitting packet data in radio telephone TDMA systems

(57) The invention relates to a method for transmitting packet data in a cellular system. The number of time slots in a TDMA frame dedicated for packet transmission varies according to transmission needs and each logical channel consisting of corresponding time slots in consecutive TDMA frames is independent of the other logical channels. A data packet is encoded in an information channel frame consisting of N-1 information bursts, and between the frames there can be an acknowledge/retransmission request burst (ARQ) reporting that a received frame was error-free or requesting retransmission. Thus, the information channel consists of repeated sequences of N bursts. Also disclosed are the structure of a packet paging burst (PP), packet random access burst (PRA), packet access grant burst (PAG), acknowledge/retransmission request burst (ARQ) as well as the use of the bursts in starting and maintaining the transmission.

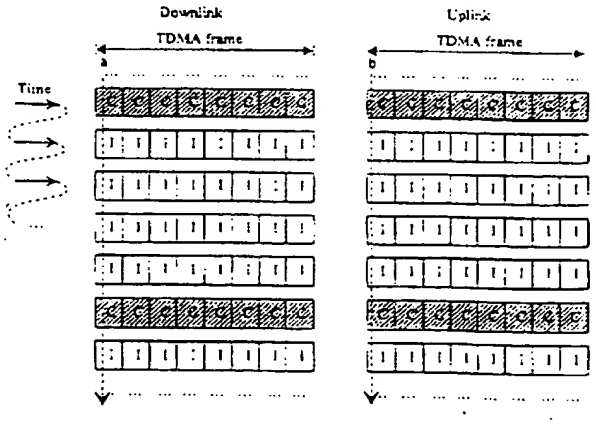


Fig. 3

EP 0 687 078 A2



BNSDOCID: <EP 0687078A2>

This invention relates to the transmission of packet data having flexible variable rate reservation access for TDMA-based cellular systems.

Typically, cellular systems offer efficient data and speech services based on circuit switched technology. In circuit switching, however, the use of transmission resources is not optimal since the transmission link is maintained for the whole duration of the connection independent of whether or not information is being sent at a given moment. Transmission resources are also shared by many other users, and therefore maintaining a circuit switched connection for one user unnecessarily wastes the transmission resources for other users. The fact that data services are transmitted in bursts is also a disadvantage in circuit switching. Channel utilization can be improved and optimized by using packet switched transmission of information.

There have been several research projects to study packet radio for optimizing the use of channels in burst data traffic. Time division multiple access (TDMA) was not utilized in older systems. More recent research projects have studied time division based packet radio systems' capable of reserving multiple time slots per use; in other words, capable of data transmission with high data rates.

A future third generation cellular system called the universal mobile telecommunication system (UMTS) has to be capable of performing both circuit switched and packet transmission, like integrated services digital network (ISDN) transmission and asynchronous transfer mode (ATM) transmission. The key factor is an air interface utilizing advanced multiple access technology for efficiently multiplexing, at the air interface, channels supporting various types of services to and from the radio path. Requirements set by the UMTS system for the air interface have been described in the article "A Reservation Based Multiple Access Scheme for a Future Universal Mobile Telecommunications System" by J.M. DeVille, published in the Mobile and Personal Communications, 13-15 December 1993, Conference Publication No. 387, IEE 1993. The multiple access has to be capable of utilizing the inactivity of the information source by assigning a physical channel only when there is activity on the logical channel and, furthermore, be capable of supporting various bit rates so that, when necessary, time slots in a frame are assigned for the logical channel.

To meet these and other requirements a multiple access control method has been proposed called packet reservation multiple access (PRMA + +) which is part of the proposal for third-generation cellular systems in relation to the transmission of packeted speech and data. The PRMA + + can be used as multiple access control both in packet switched and circuit switched transmission. The PRMA + + method concentrates on the use of one time slot in the transmission of packet data. This mechanism provides an efficient multi-slot/multi-user environment for a system having a high number of time slots in its TDMA frame.

The PRMA + + uses time division multiple access TDMA in the radio channel. This makes it possible for a user to share radio channel transmission resources. Now follows a description of this system, with reference to Figure 1. A TDMA frame is divided into time slots in which a transmitted burst carries data and signalling associated with channel coding, detection, etc. In the uplink direction, ie. from a mobile station to a network (base station), there are two types of time slots: reservation time slots, or, R-slots which are used only for transmitting channel request bursts; and information time slots, or, I-slots used only for transmitting information bursts. In a channel request burst a mobile station uses a so-called air interface channel identifier including the mobile station's network address that identifies the logical channel and requesting one or more time slots of a frame for its use according to the need at that moment. In the downlink direction, ie. from a network (base station) to a mobile station, there are also two types of time slots: I-slots for transmitting information and A-slots, or, acknowledge time slots. When a mobile station requests access to the network, the base station acknowledges the request with A-slots by sending the requesting station's address and the number of the I-slot. From then on, that I-slot is reserved for the mobile station.

Let the number N of PRMA + + time slots available in one TDMA frame be a system configuration parameter. Then, in the uplink channel there is in one TDMA frame, one reservation time slot (R-slot) and N-1 information time slots (I-slots). All mobile stations begin transmission by sending a channel request in the R-slot and if several mobile stations use the same R-slot for sending the request, collisions may occur. In the downlink channel, there is also in a TDMA frame, in addition to the I-slots and the above-mentioned A-slot for acknowledging channel reservation requests sent in the R-slot, a fast paging time slot (FP-slot) for informing a mobile station about an incoming data transmission and the information transmission time slots.

A mobile station initiates a connection by sending a channel request on an uplink channel, in the R-slot used for this purpose by all mobile stations of a cell. The base station acknowledges the channel request with a downlink acknowledge burst in the A-slot. If no requests are sent in the R-slot or if there are collisions on the channel recognized by the base station, it sends an "idle" flag in the acknowledge burst of the corresponding A-slot and then the mobile station knows that it should send the channel request again after a while. In the case that a channel request sent in the R-slot was received without problems but there



BNSDOCID: <EP 0687078A2>

are no free time slots for transmission, the mobile station will be informed about the matter in the next downlink acknowledge time slot. The mobile station will queue for access until a free time slot is found.

An R-slot includes a training sequence, the address of the mobile station, the number of requested information time slots, and the circuit switching flag. The flag tells whether the reservation is valid for the duration of the packet or for a longer time. The channel is reserved until an instruction is given to release the reservation. The acknowledge burst in the A-slot includes the address of the mobile station requesting a channel and the channels dedicated for traffic. The mobile station receives the acknowledge burst and then sets the receiver and transmitter to the defined channel. Traffic on the channel is begun and it continues as long as there are data or speech to transmit. In packet data transmission, the number of bursts - or, in this case, packets - sent after one channel request can be fixed.

A base station uses the fast paging time slot (FP-slot) to inform a mobile station about an incoming packet. A mobile station listens to the fast paging channel and decodes all incoming messages to find its own code. The fast paging time slot includes a list of the I-slots that have been allocated to the mobile station. A mobile station acknowledges a paging call by sending an acknowledge in the fast paging acknowledge time slot (FP-ack).

Accordingly, it is characteristic of the proposed UMTS system that both uplink and downlink connections that are inactive at a given moment are not allocated physical channels during that time, which prevents unnecessary use of resources. Channels are always reserved using the same method independent of whether the connection is a circuit switched or a packet connection. One disadvantage of this known system is that the allocation of channels is not dynamic and, therefore, it is not easy to change the channels reserved for packet use. The reservation, paging, and acknowledge time slots are certain time slots and prior art systems take no position in the changing of those time slots. In addition, the known system does not particularly take into account the symmetry or asymmetry of the packet transmission when setting up a transmission channel. Hence, there is the disadvantage of the system not being very flexible. It is true the system is good with a great number of time slots but with a variable number of time slots, say, one or two, the system is not easily configurable.

According to the present invention there is provided a time division multiple access (TDMA) radio telephone system for transmitting packet data including

a base station and a mobile station,

at least one logical channel comprising a TDMA slot for packet data communication between the base station and the mobile station,

a control channel (C) comprising slots temporally spaced apart by a group of consecutive slots of at least one logical channel, and

an information channel (I) comprising the group of consecutive slots separating the slots comprising the control channel (C).

This has the advantage that each logical channel reserved for packet data transmission is independent of any others. Thereby, facilitating the variation by a network of the number of packet data channels available to users. Thus, a network can dynamically allocate channels for packet data transmission according to need. Thus, only channels needed for packet data transmission are reserved as such.

In a preferred embodiment the control channel (C) includes an acknowledge/retransmission request burst (ARQ) for indicating error-free received data. Thus, if error-free data was not received or the data could not be reconstructed, retransmission of the data can be requested.

Preferably, the logical channel is a downlink logical channel for transmitting from the base station to the mobile station, and the control channel (C) is capable of transmitting packet paging (PP) data for informing the mobile station of incoming packet data.

Optionally, the control channel (C) is capable of transmitting a packet access grant PAG signal for acknowledging a channel reservation request (PRA) transmitted from the mobile station. Thus, the control channel is capable of acting as a reservation request acknowledge channel.

This invention proposes a flexible system in which time slots reserved for packet data can be changed according to need.

The multi-slot concept described below is based on channel independence: all physical radio channels are alike and one or more channels, up to the maximum number, can be dedicated for packet use. The media access control (MAC) algorithm of the layer above the physical layer is independent of the number of time slots in use. So the operator is free to launch the packet data transmission service using only a few time slots in a TDMA frame and, as the need arises, to upgrade the service using all time slots in a TDMA frame. If the application is e.g. GSM or DCS 1800 or some such derivative, one frame includes 8 time slots and it is therefore possible to dedicate from one to eight time slots for packet data use. Even if the network supports multi-slot transmission a mobile station is still free to use only one time slot. Then even a simple mobile station is able to use the packet data service provided by the network.

A high-capacity cell can be built by dedicating more than one carrier wave for the packet radio service. The algorithm is independent of the number of time slots dedicated by the operator. An operator can start with one time slot and upgrade the service up to 8 time slots when the number of packet radio users grows.



BNSDOCID: <EP 0687078A2>

Naturally, the number of carriers can also be increased, which means that multiple independent carriers are used.

An embodiment in accordance with the invention is described below, by way of example only, with reference to the enclosed drawings, and in which:

Figure 1 shows the frame structure of the proposed UMTS system;

Figure 2 shows the logical channel structure in a system in accordance with the invention;

Figure 3 shows the channel structure of a system using eight time slots;

Figure 4 shows the structure of the combined paging and acknowledge time slot;

Figure 5 shows an example of the bit contents of the fields presented in Figure 4;

Figure 6 shows an example of the structure of the paging time slot;

Figure 7 shows an example of the bit contents of the paging time slot;

Figure 8 shows the structure of the packet access grant time slot,

Figure 9 shows an example of the bit contents of the packet access grant time slot;

Figure 10 shows the structure of the packet random access burst;

Figure 11 shows an example of the bit contents of the packet random access burst;

Figure 12 shows the signalling chart of mobile originated packet transmission;

Figure 13 shows the state transitions in mobile originated packet transmission;

Figure 14 shows the signalling chart of mobile terminated packet transmission;

Figure 15 shows the state transitions in mobile terminated packet transmission; and

Figure 16 shows variations of control time slots in a TDMA frame.

A "frame" in this description means consecutive time slots of a logical channel, not consecutive TDMA frames with their time slots unless specifically described as such, of which there are eight in the GSM system, for example.

Referring to Figures 2 and 3. Figure 3 shows downlink and uplink frames as seen from a base station in an 8-time-slot TDMA system. The structure in Figures 2 and 3 can be combined e.g. with GSM 51 multiframes if needed. In one of the TDMA frames going to the cell the base station sends only control data C, and all time slots of the next four frames include information I that can be packet data. In such a case, the number ot information frames per unit time is decreased, resulting in a decrease in information rate also.

Correspondingly, when the base station is receiving from the cell (uplink direction), one TDMA frame includes only control time slots C used for receiving requests, acknowledges, etc. sent by mobile stations. The next four TDMA frames include only time slots for receiving information I. Let us now consider the situation from the point of view of one mobile station. A base station sends control or information to one mobile station in the same time slot of each TDMA frame. So the time slots sent to one mobile station are the time slots marked with the dotted arrow a. Hence, the mobile station receives one control burst in the time slot C and, after that, information I in four consecutive bursts if there is information for that mobile. This sequence is called a frame in this description. Frames are received as long as there is something to receive. Correspondingly, a base station will receive from one mobile station in consecutive time slots marked with the dotted arrow b. The sequence consisting of a control time slot C and four consecutive information time slots I is called a frame in this description.

Figure 2 shows the (dedicated) frame structure. Uplink frames consist of time slots marked with the dotted arrow b in Figure 3 as explained above and, correspondingly, downlink frames consist of time slots marked with the dotted arrow a.

This description involves a case in which four bursts are used, as explained above, but an I frame may also be longer or shorter. A four-burst I frame is only one alternative and it is possible to use TDMA frames of another length (8 bursts, for example). This is an optimization problem: the longer the frame, the longer the access delay and minimum packet size. Thus, the length of the frame in the physical layer is a system parameter.

When encoding four-burst frames in the physical layer, it is possible to use the same coding as on the stand-alone dedicated control channel (SDCCH) in the known GSM system. This code has a frame length of four bursts, or 456 bits. (A 228-bit block consisting of 184 bits of user data, 40 parity bits, and 4 tail bits is convolutionally encoded into 456 bits.) The interleaving depth is 4. The interleaving depth of 4, compared to 19 in circuit switched data transfer, reduces the transmission delay and minimum packet size. Alternatively, some other code, like Reed-Solomon, could be used to encode the frames.

Let us now consider the physical layer, with reference to Figure 2 which should be interpreted as follows. If a base station is receiving packet data, the reception occurs in the gray I time slots. The base station sends an acknowledge in the downlink ARQ time slot. Hence, the connection is made up of the gray time slots. Correspondingly, when the base station is transmitting packet data, the connection is made up of the white time slots.

In layer 1 (the physical layer), an automatic retransmission request (ARQ) is used in a control time slot C to decrease the frame error rate when transferring from the physical layer to the upper layers. However, the use of ARQ is optional and need not be utilised nor included in the system. A data frame consists



BNSDOCID: <EP 0687078A2>

of 4 bursts which have had the error correction coding and frame check done for them. In this example, every fifth burst both in the downlink and uplink directions is used for control purposes. The frequency of control bursts may of course be increased from the proposed every fifth, optimizing efficiency and the power consumption of the mobile station. In the downlink direction, a control burst, including a retransmission request ARQ, is transmitted as a normal burst. In the uplink direction, the ARQ is transmitted in an access-like burst with a long training sequence. Then the data part of the burst will not include a random number as usual but those bits will be replaced by ARQ bits. Hence, only a small part of an access-type control burst (here it is proposed 12 bits) is used for the retransmission request ARQ. A mobile station that does not know the exact timing advance is then able to transmit an ARQ burst. In the uplink direction, the control bursts include only ARQ bits.

Having transmitted the four-burst frame a transmitter/receiver will listen to the frame acknowledge. An erroneous frame will be immediately retransmitted and if the frame is correctly received, the transmission continues. The frames can be numbered to indicate the correct frames when requesting an automatic retransmission. The ARQ acknowledge has the same frame number which it will selectively acknowledge. It is even possible that every burst has a separately encoded block which is numbered.

The raw information bit rate is about 19.7 kbps on one TCH/F channel with this configuration. By using all eight TDMA time slots for one Mobile Station (MS) the raw bit rate is about 158 kbps. The automatic retransmission request is used over the radio path, ie. between a MS and base station BTS.

Above we discussed the physical layer in a system in accordance with the invention. Next we will have a look at the control layer MAC (multiple access control or media access control) above the physical layer. The control layer is used for transferring high level control messages. Still referring to Figure 3. The MAC algorithm is on top of layer 1, ie. every fifth burst is used for control purposes. Uplink and downlink channels are used asymmetrically and independently. The asymmetric use of a physical channel makes it possible to optimize the efficient use of channels. Data are usually sent in bursts with short intervals in one direction at a time. During another short interval the data flow may be in the opposite direction. This is carried out by separate channel allocation. Independence means that both uplink and downlink directions can be reserved independently of each other. The method can also be used symmetrically whereby uplink and downlink channels are reserved in pairs.

The high level control messages carried in the downlink control time slots C are packet paging P and packet access grant PAG. In the uplink, there is no special high level control time slot but a mobile station can send a packet random access (PRA) burst in any free I time slot to request a channel. In the physical layer, there is a special control time slot in the uplink direction and it is used for the ARQ.

Let us next consider a control time slot in the MAC layer. Both the packet paging P and the packet access grant PAG can be combined in one burst of a control time slot C or the paging and request may be sent in separate control time slots C. Having the packet paging P and the packet access grant PAG in the same control burst is the optimal case, and that is possible if the number of bits available in one burst in the cellular system is sufficient. Control bursts are encoded independently, ie. no interleaving is used.

Now referring to Figure 4 illustrating the first alternative, ie. the structure of a combined acknowledge and paging burst. A base station managing the radio resources monitors the states of the channels; in other words, which channels are free and which are reserved. It transmits a bitmap of free uplink channels in every downlink control burst as part of the burst; in Figure 4, right at the beginning of the burst. The bitmap indicates to the mobile station the idle channels at that moment on which it can send a packet channel request in the form of an access burst. Also included in the control burst are the packet paging, packet access grant, and the automatic retransmission request ARQ of the physical layer. The packet paging P part of the burst is used for informing the mobile station about incoming packet data transmission. The paging also includes the temporary packet mobile identity TMPI, temporary logical link identity TLLI in GSM GRPS, and a description of the channels reserved by the network for the mobile terminated data transmission. The third part of the control burst, the packet access grant PAG, includes a random number used to distinguish various requesters, a bitmap of the channels reserved for the connection, and the timing advance TA. The last part of the burst includes an ARQ for acknowledging layer 1 messages.

If the combined P and PAG burst were applied in the known GSM cellular system, the bit contents of the burst fields could be as shown in the exemplary table of Figure 5. The P and PAG together would take up 55 bits and ARQ 12 bits, thus making up a total of 67 bits in the burst. The combined burst can be used in any application system provided that the number of information bits in the burst is sufficient, ie. the number of information bits is the same or higher than in the GSM system.

Figures 6 and 8 illustrate another alternative for transferring paging and acknowledge bursts. The bursts are sent separately with the P and PAG in their own control bursts. The P and PAG time slots share the downlink control channel. These time slots are sent alternately, for example. Every other control time slot C is for the paging P and every other for the acknowledge PAG. A mobile station will distinguish



BNSDOCID: <EP 0687078A2>

between paging and acknowledge by checking the steal bit in the burst. A P time slot will have "1" as the steal bit and a PAG time slot will have a "0" or vice versa. Occasionally there might be a need to send a packet access grant PAG instead of a packet paging P if there are no packet pagings coming to the cell at that moment. This can be done by stealing the P time slot for the PAG and notifying the mobile station with the steal bit.

As shown in Figure 6, the separate packet paging burst structure includes first the bitmap to indicate free/reserved channels. The bitmap consists of 8 consecutive bits if the TDMA frame is 8 time slots. The next field is the paging field in which the first part is the temporary mobile identity TMPI and the second part a bitmap which indicates to the mobile station the channels reserved by the network for the transmission of packet data, which the mobile station has to use for receiving packet data. Finally, there is the field for the automatic retransmission request. Figure 7 shows as an example the bit contents of the paging field when the cellular network is a GSM network. The field includes 60 bits if the TMPI is the GSM's temporary mobile subscriber identity TMSI. A shorter TMPI, 25 bits, for example, will suffice.

As shown in Figure 8, the separate packet access grant PAG burst includes first a bitmap to indicate free/reserved channels. The next field is the acknowledge field for the packet random access sent by a mobile station. There the first part is a random number included in the request sent by the MS. Then follows a bitmap that indicates to the mobile station the channels reserved by the network for the transmission of packet data. The mobile station will use these channels to send packet data. Finally, there is the field for the automatic retransmission request. The random number used in the request is used to indicate the packet access grant to a specific mobile station (mapping of PRA to PAG). Mobile stations in the cell will listen during this time slot and the random number will tell a particular mobile station that the acknowledge is meant for it. To decrease the probability of collision (should two mobile stations select the same random number) it is possible to use for the identification either the number of requested time slots or the priority or the time slot number of the packet random access (PRA) time slot (which refers to the time slot which the mobile station used for requesting a channel). These parameters are not shown in Figure 8.

The table in Figure 9 shows the bit contents of the control time slot presented in Figure 8 if the application system is the GSM. The bits indicating the number of requested time slots as well as those indicating the priority are optional.

So far we have described an embodiment of the inventive system mainly from the point of view of a base station. Let us now consider the transmission from a mobile station to a base station. The base station schedules the reservation of an uplink channel. It has the knowledge of free and reserved channels and that information is transmitted in every downlink control burst, as explained above. The bitmap consists of 8 bits, one for each time slot in a TDMA frame if the frame is a TDMA frame with 8 time slots. The reserved channels are marked with bit 1 and idle channels with bit 0. If the network is not using all 8 time slots for the packet transmission service, then only those channels that are used may be marked idle. The rest of the channels are treated as if they were reserved, ie. bit 1 is sent.

Referring to Figure 10. A mobile station which has data in its buffer and wants to send it monitors the control bursts sent in the downlink C time slots. Monitoring is continued until the bitmap shows that an uplink channel is marked idle. As soon as the idle channel is found, an access burst (channel request) according to Figure 10 is transmitted in an I time slot marked idle. This burst carrying the packet random access burst PRA is randomly selected as one of four, for example, if the frame used is four bursts. The packet random access PRA is similar to the access burst in the GSM system, for example, with a long training sequence. Then the data part of the burst will not include a random number as usual but those bits will be replaced by the PRA bits. Because of the long training sequence a mobile station which does not know the exact timing advance is able to send a PRA burst without problems. Possible collisions occurring when more than one mobile stations request a channel in the same time slot are handled with a back-off algorithm. An access burst consists of a random number sent back by the base station in the acknowledge burst, a number indicating how many time slots the mobile station wants, a four-level priority number, and finally a bit indicating whether or not the time slots have to be consecutive. The requirement for consecutive time slots is needed to support certain mobile classes. There might be a mobile station capable of handling, say, two packet time slots if they are consecutive in a TDMA frame but not if the time slots are a distance apart.

Figure 11 shows the possible bit contents of the fields. The burst consists of at least 11 bits. As soon as a base station receives an access burst PRA, it sends a packet access grant PAG in a downlink control burst C. If multiple consecutive access bursts are received before the next packet access grant can be transmitted, the priority or random selection is used to assign the channel for a mobile station. If there are not as many time slots available as requested, the base station can give as many as there are free.

When a mobile station has received an acknowledge PAG sent by a base station for a channel request PRA it starts to transmit packet data on the reserved channel consisting of one or more time slots, up to the maximum amount. It is possible to transmit during



BNSDOCID: <EP 0687078A2>

one reservation at least 128 octets which is the usual X.25 maximum packet size. 128 octets equals six 4-octet blocks. This means that the maximum amount of data transmitted during one reservation depends on the number of time slots used and that there has to be a limit value set in case the transmission fails and a retransmission is required. The limit value has to be more than 6, because in the case of retransmission 6 frames will not be enough to transmit all.

Figure 12 shows a signalling chart for mobile originated packets. A mobile station MS sends a channel request PRA acknowledged by a base station in a packet access grant burst PAG. The mobile station transmits packet data in time slots of one frame and the base station acknowledges or sends a retransmission request. This goes on until all packet data have been transmitted or time-out occurs.

Figure 13 is a state transition diagram illustrating the events in a mobile station during packet transmission from a base station to the network. When the data buffer is full, the mobile station goes from idle state to receive state and receives the information in the first control time slot from the base station. It consults the bitmap to see whether there are any free channels, and if not, checks the information in the next control time slot. This goes on until a free channel is found. Immediately after that, a channel request is sent on the free channel and if the base station acknowledges, packet data is transmitted on the dedicated channel. If no acknowledge is received, the mobile station returns to receive control time slots and search for a free channel.

Figure 14 illustrates a case where a network sends packet data addressed to a mobile station MS. A base station initiates a downlink transmission by sending a packet paging P in a control time slot C. The packet paging includes the mobile station identity and the reserved time slots. These time slots begin in the next TDMA frame. As soon as the MS receives the packet paging it starts receiving in the defined time slots.

Packet pagings are transmitted in every consecutive time slot of a downlink control sequence to inform mobile stations about incoming packets. This means that a mobile station must listen to all packet paging channels in order to find out if there are packets coming to it. This of course uses energy stored in the mobile station's battery. To optimize the power consumption mobile stations can be divided into different paging groups according to the temporary identity or IMSI, for example. Then a mobile station has to listen to only one time slot in a TDMA frame instead of all the time slots. There can be eight time slots, so it is more practical to listen to one time slot only. The paging frequency can be still decreased to support discontinuous reception DRX. This, however, increases the delay and therefore the DRX should be a selectable mode for a mobile station. The DRX power saving function can also be combined with the paging burst used in the present GSM system by adding the code "incoming packet" in the burst. Then a mobile station will listen to standard pagings and the code will inform it about an incoming packet transmission. Then the mobile station will start listening to the packet paging channel P and receive the necessary information from that channel. Of course, the network needs to know whether the mobile station is listening to the standard paging channel or the packet paging channel. The mobile station sends this information in a short management message.

If the base station does not receive an ARQ acknowledge in a certain number of frames, say, in seven frames, it draws the conclusion that the mobile station is not receiving frames correctly. Then the packet paging will be repeated.

Figure 15 shows a mobile station state transition diagram for the case presented in Figure 14. Understanding the diagram is easy on the basis of the description related to Figure 14, so further explanations are not needed. It is, however, pointed out that most of the time the mobile station is receiving control bursts and determining if there is a packet data transmission coming to it.

The frame used in the data link layer may be variable in length. A maximum length of, say, 128 octets, as in the X.25 protocol, can be chosen. A variable length reduces the number of acknowledges in the link layer and thus the number of reservations.

The system may be implemented in many ways within the scope of the invention defined by the claims set forth below. For example, the control time slots need not be as shown in Figure 3 but they can be moved diagonally, as illustrated by Figure 16.

In each frame, the control time slot C is moved forward one time slot, thus creating a diagonal pattern of control time slots both in the uplink and downlink frames as shown in Figure 16. A dedicated frame, however, still consists of a control time slot C and four information time slots I, as in the case illustrated by Figure 3.

The scope of the present disclosure includes any novel feature or combination of features disclosed therein either explicitly or implicitly or any generalisation thereof irrespective of whether or not it relates to the claimed invention or mitigates any or all of the problems addressed by the present invention. The applicant hereby gives notice that new claims may be formulated to such features during prosecution of this application or of any such further application derived therefrom.

## Claims

1. A time division multiple access (TDMA) radio telephone system for transmitting packet data in-



BNSDOCID: <EP 0687078A2>

cluding

a base station and a mobile station,

at least one logical channel comprising a TDMA slot for packet data communication between the base station and the mobile state,

the at least one logical channel having a control channel (C) comprising slots temporally spaced apart by a group of consecutive slots, and an information channel (I) comprising the group of consecutive slots separating the slots comprising the control channel (C).

2. A system according to claim 1, wherein the control channel (C) includes an acknowledge/retransmission request burst (ARQ) for indicating error-free received data.

3. A system according to claim 1 or claim 2, wherein the logical channel is a downlink logical channel for transmitting from the base station to the mobile station, and the control channel (C) is capable of transmitting packet paging (PP) data for informing the mobile station of incoming packet data.

4. A system according to claim 3, wherein the control channel (C) is capable of transmitting a packet access grant PAG signal for acknowledging a channel reservation request (PRA) transmitted from the mobile station.

5. A system according to claim 4, wherein the packet access grant (PAG) signal includes a bitmap indicating which time slots have been reserved for uplink packet data transmission.

6. A system according to claim 3 or claim 4, wherein the packet paging (PP) data includes a bitmap indicating which time slots are reserved for downlink packet data transmission.

7. A system according to any preceding claim, responsive to a channel reservation request (PRA) in the form of a system access type burst and including information on how many time slots the mobile station wants to be reserved for packet data transmission.

8. A system according to claim 4 wherein in the downlink direction the acknowledge/retransmission request burst (ARQ) is part of a combined control channel burst (C) which includes both a packet paging (PP) and a packet access grant (PAG).

9. A system according to claim 3, wherein in the downlink direction the acknowledge/retransmission request burst (ARQ) is part of a control burst (C) which also includes a packet paging (PP).

10. A system according to claim 2 wherein in the downlink direction the acknowledge/retransmission request burst (ARQ) is part of a control burst (C) which also includes a packet access grant (PAG).

11. A system according to any of claims 8, 9 or 10, wherein the control burst (C) includes a bitmap indicating free and reserved logical channels in the uplink direction.

12. A system according to claims 9 and 10 wherein the packet paging (PP) and the packet access grant (PAG) signal are sent in alternate time slots of the control channel (C) and both bursts include an identifier with which a mobile station can distinguish one from the other.

13. A system according to claims 9 and 10 wherein only packet access grant (PAG) signals are sent in the time slots of the control channel (C) if there are no packet pagings (PP) to send and the burst includes an identifier with which a mobile station can distinguish one from the other.

14. A system according to any preceding claim wherein for transmitting packet data from a mobile station to a base station the mobile station is adapted to monitor control bursts transmitted on the downlink channel until a free channel dedicated for information transfer is identified in the bitmap,

in a time slot of said identified channel the mobile station is adapted to transmit a channel reservation request (PRA), and in response to receiving a packet access grant (PAG) signal from the base station the mobile station is adapted to transmit packet data on the identified channel.

15. A system according to claim 14, wherein the channel reservation request (PRA) signal comprises data indicative of a mobile station identifier, the number of time slots required for packet data transmission, and the priority of the request.

16. A system according to claim 15, wherein the channel reservation request (PRA) signal further comprises data indicative of whether or not the time slots have to be consecutive.

17. A system according to any claim dependent on claim 3 , wherein a mobile station listens to packet pagings (PP) only on channel assigned to it.

18. A system according to claim 17 wherein on said channel, packet pagings (PP) are transmitted



BNSDOCID: <EP 0687078A2>

only in predetermined control time slots known to the mobile station and the mobile station listens to packet pagings (PP) only during those time slots.

19. A system according to any claim dependent on claim 3, wherein a mobile station listens to normal paging calls of the system for an identifier indicating an incoming packet data transmission, and responsive to detection of said identifier the mobile station starts listening to packet data pagings (PP).

20. A system according to claim 7, wherein the channel reservation request (PRA) signal includes an identifier indicating how many information channel time slots there has to be immediately one after the other.

21. A system according to any claim dependent on claim 3 wherein a packet paging (PP) is transmitted in every time slot of a TDMA frame.



BNSDOCID: <EP 0687078A2>

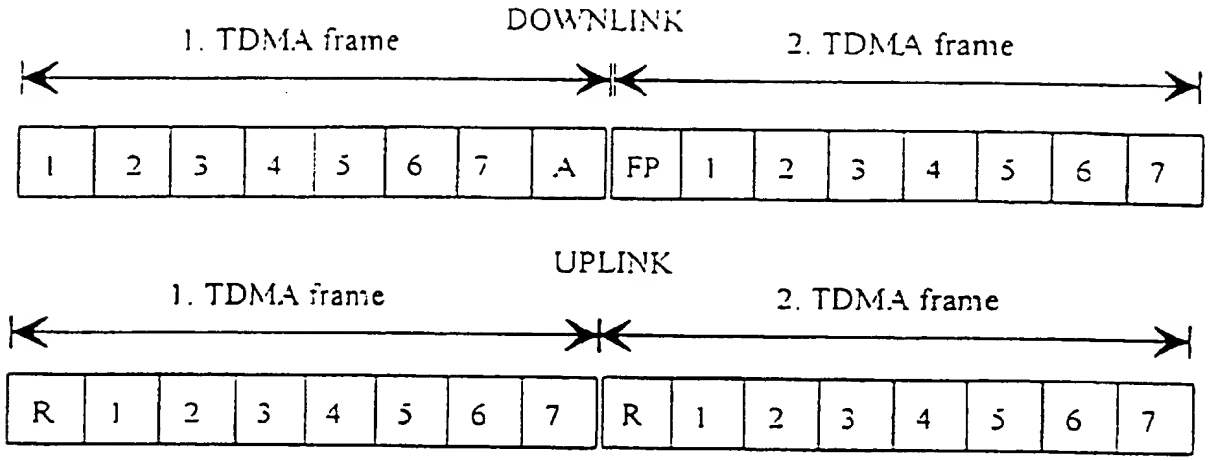


Fig. 1

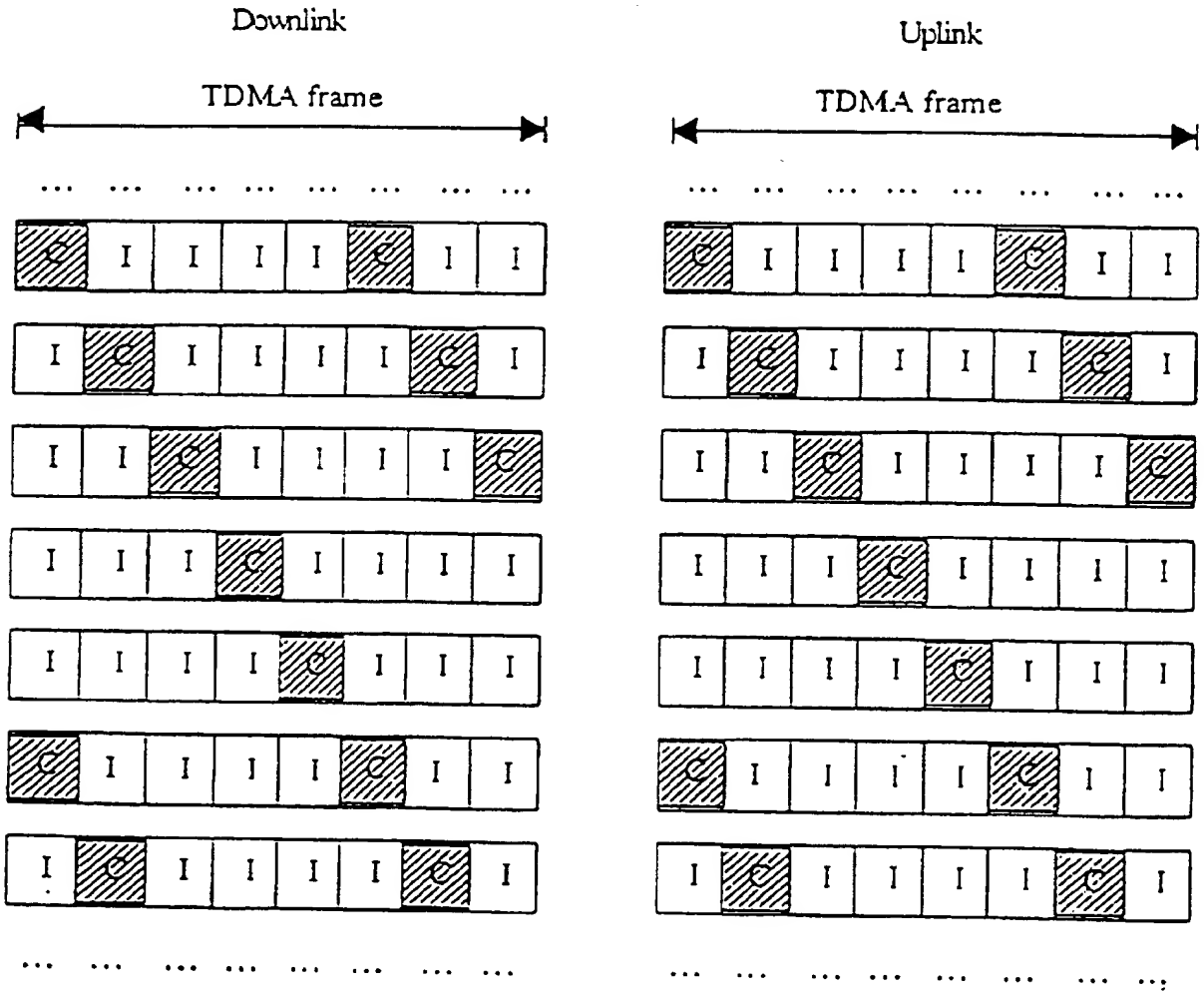


Fig. 16



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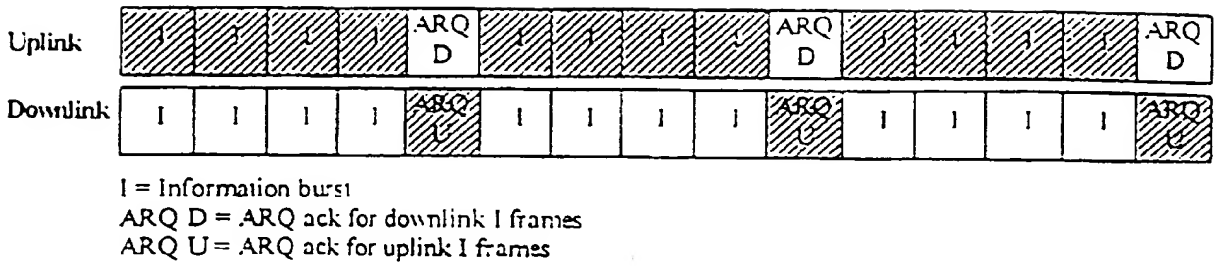


I = Information burst
ARQ D = ARQ ack for downlink I frames
ARQ U = ARQ ack for uplink I frames

Fig. 2

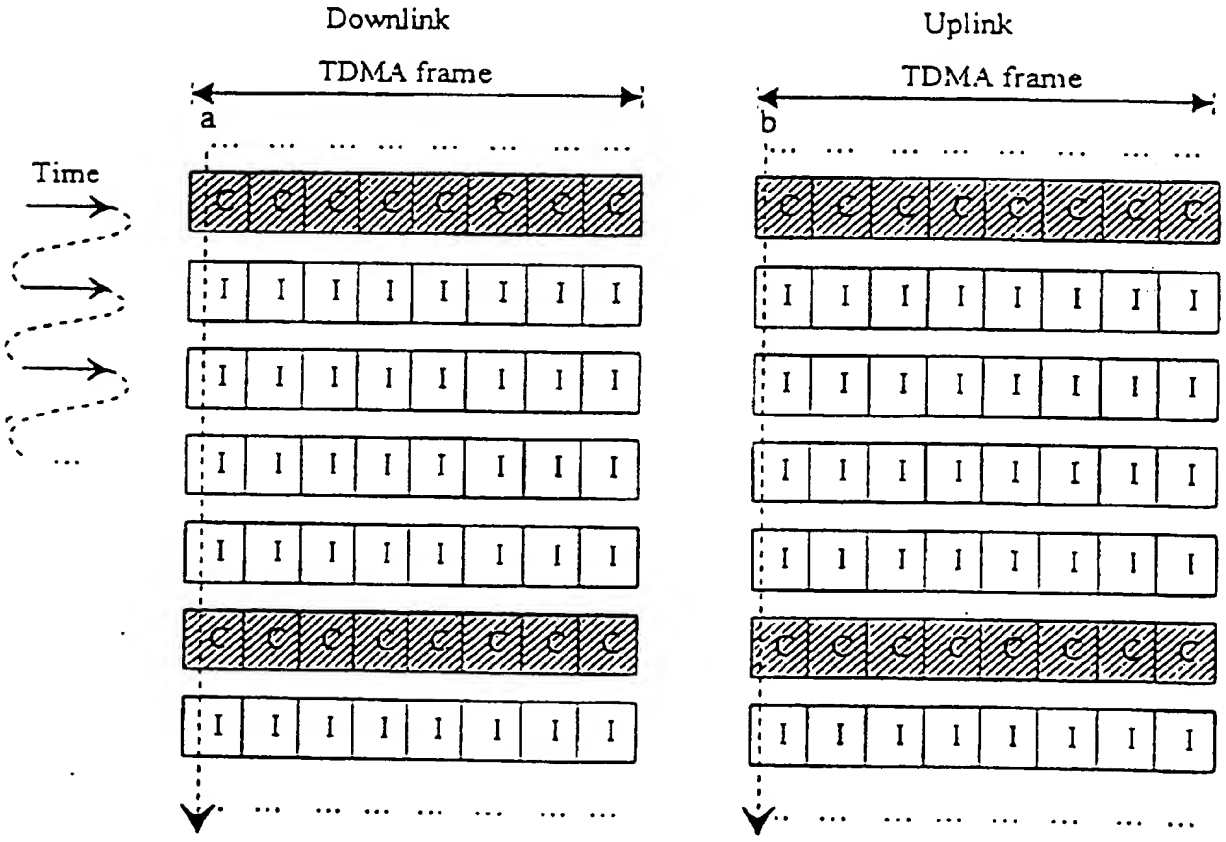


Fig. 3



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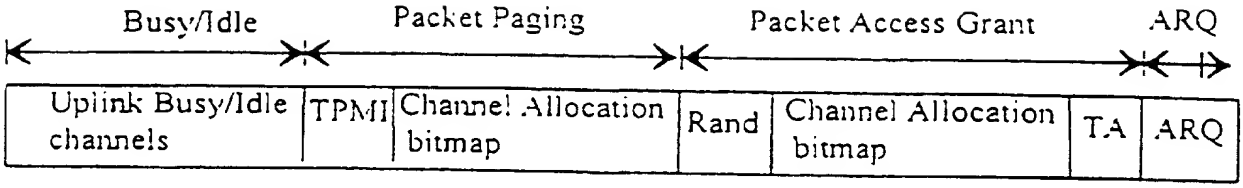


Fig. 4

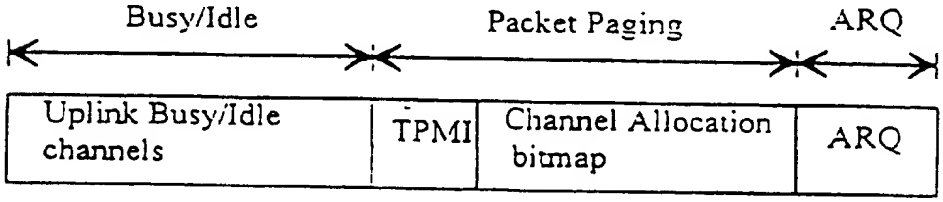


Fig. 6

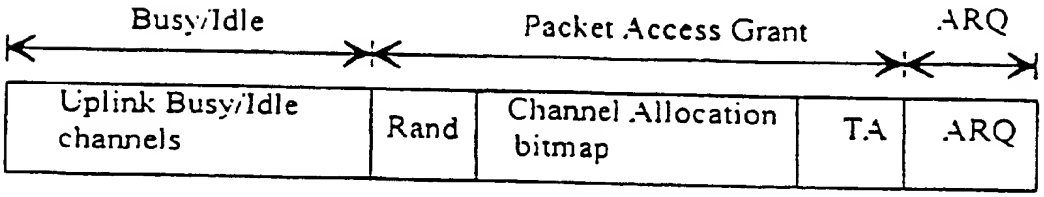


Fig. 8



BNSDOCID: <EP 0687078A2>

| FIELD CONTENTS | POSSIBLE NUMBER OF DATA BITS |
|---|---|
| bitmap of free/reserved uplink channels | 8 bits |
| TMPI (temporary packet mobile ID) | 25 bits |
| channel allocation bitmap (for paging) | max 8 bits |
| random number | 8 bits |
| channel allocation bit map (for acknowledge) | max 8 bits |
| timing advance TA | 6 bits |
| automatic retransmission request ARQ | 12 bits |

Fig. 5

| FIELD CONTENTS | POSSIBLE NUMBER OF DATA BITS |
|---|---|
| TMPI (temporary packet mobile ID) | max 25 bits |
| channel allocation bit map | 8 bits |
| ARQ acknowledge (L1 ARQ) | 12 bits |
| bitmap of free uplink channels | 8 bits |

Fig. 7

| FIELD CONTENTS | POSSIBLE NUMBER OF DATA BITS |
|---|---|
| random number included in PRA | 5 bits (or 12 if modified access burst) |
| (number of requested time slots) | 3 bits |
| (priority)) | 2 bits or more |
| channel allocation bitmap | 8 bits |
| timing advance TA | 6 bits |
| ARQ acknoqledge (L1 ARQ) | 12 bits |
| bitmap of free uplink channels | 8 bits |

Fig. 9

| FIELD CONTENTS | POSSIBLE NUMBER OF DATA BITS |
|---|---|
| random number (as in GSM) | 5 bits or more |
| number of time slots needed | 3 bits |
| priority (4 levels) | 2 bits |
| requirement for consecutive time slots | 1 bits |

Fig. 11



BNSDOCID: <EP 0687078A2>

| Random number | No. of time slots | Priority | Consec. |
|---|---|---|---|

Fig. 10

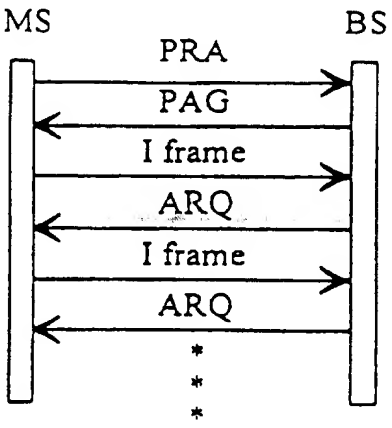


Fig. 12

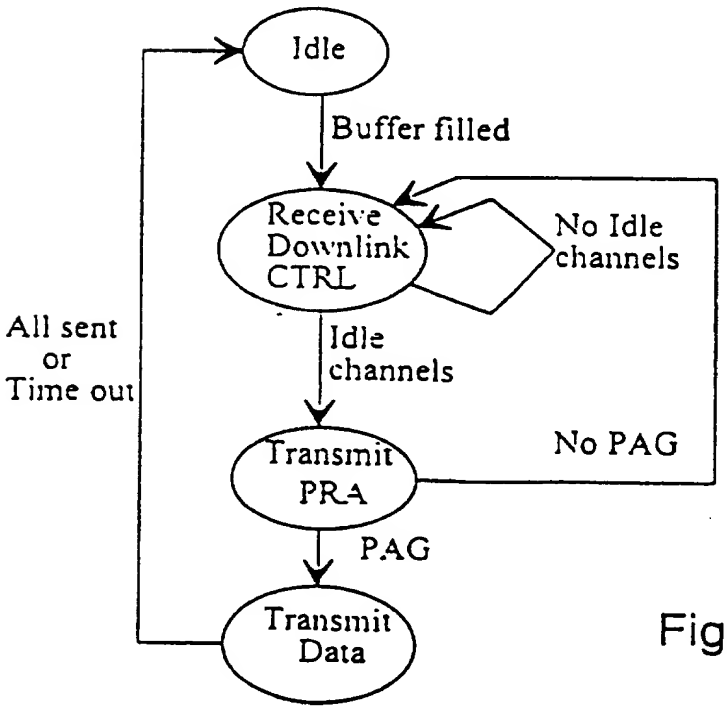


Fig. 13



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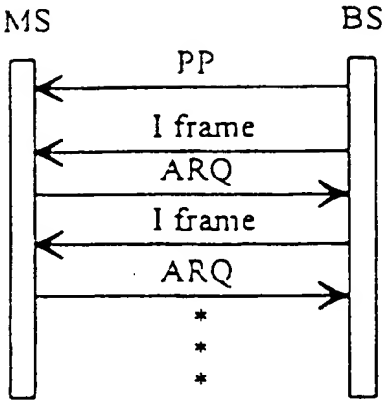


Fig. 14

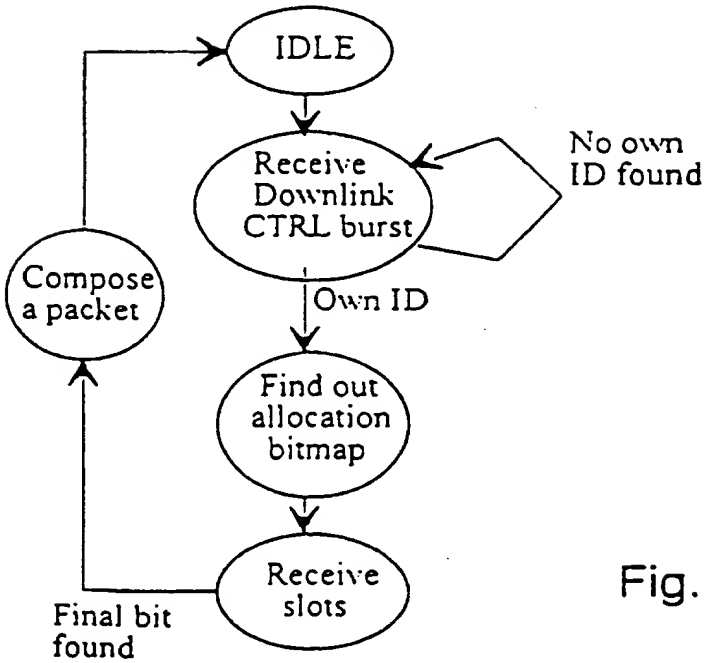


Fig. 15



BNSDOCID: <EP 0687078A2>

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## (54) A system for transmitting packet data in radio telephone TDMA systems

(57) The invention relates to a method for transmitting packet data in a cellular system. The number of time slots in a TDMA frame dedicated for packet transmission varies according to transmission needs and each logical channel consisting of corresponding time slots in consecutive TDMA frames is independent of the other logical channels. A data packet is encoded in an information channel frame consisting of N-1 information bursts, and between the frames there can be an acknowledge/retransmission request burst (ARQ) reporting that a received frame was error-free or requesting retransmission. Thus, the information channel consists of repeated sequences of N bursts. Also disclosed are the structure of a packet paging burst (PP), packet random access burst (PRA), packet access grant burst (PAG), acknowledge/retransmission request burst (ARQ) as well as the use of the bursts in starting and maintaining the transmission.

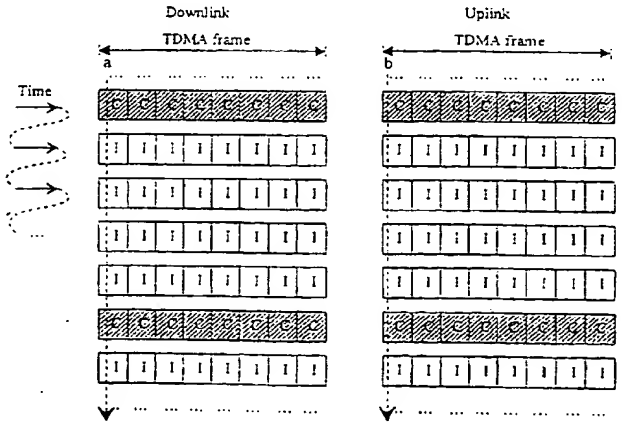


Fig. 3

EP 0 687 078 A3



BNSDOCID: <EP 0687078A3>

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# EUROPEAN SEARCH REPORT

Application Number
EP 95 30 3825

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
|---|---|---|---|
| X<br>Y | WO 94 10767 A (ERICSSON TELEFON AB L M) 11 May 1994<br>* page 6, line 6 - page 7, line 27; figure 5 *<br>* page 9, paragraph 1 * | 1,2,7<br>2-6,9, 11,14 | H04B7/26 |
| Y,D | SEVENTH IEE EUROPEAN CONFERENCE ON MOBILE AND PERSONAL COMMUNICATIONS, 13 - 15 December 1993, pages 210-215, XP000654971<br>J M DEVILE: "A RESERVATION BASED MULTIPLE SCHEME FOR A FUTURE UNIVERSAL MOBILE TELECOMMUNICATIONS SYSTEM"<br>* page 211, left-hand column, line 15 - page 212, right-hand column, line 17; figure 1 * | 2-6,9, 11,14 | |
| A | PERSONAL COMMUNICATION - FREEDOM THROUGH WIRELESS TECHNOLOGY, SECAUCUS, NJ., MAY 18 - 20, 1993, no. CONF. 43, 18 May 1993, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 909-912, XP000393328<br>ZIEGLER R A ET AL: "AN EXPERIMENTAL IMPLEMENTATION OF THE PRMA PROTOCOL FOR WIRELESS COMMUNICATION"<br>* page 909, right-hand column, line 12 - page 910, left-hand column, line 38 * | 1,2,5,6 | |

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
H04B
H04Q

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| MUNICH | 26 August 1997 | Burghardt, G |

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